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The Evolution of Research in Agricultural Technology and Rural Development: A Bibliometric Analysis

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This study presents a comprehensive bibliometric analysis of research evolution in agricultural technology and rural development. Utilizing Scopus data and advanced bibliometric tools, namely VOSviewer, the study explores influential publications, emerging themes, and collaborative networks in this multidisciplinary field. Key findings indicate a shift from foundational research on traditional farming techniques, such as manual tillage, monoculture cropping, and conventional irrigation methods, to modern focuses on climate-smart agriculture, including precision farming, agroforestry, and water-efficient irrigation systems, sustainable rural livelihoods through diversified income sources, and digital innovations such as AI-driven farm monitoring and blockchain-based supply chain management. Results reveal central themes around rural development, sustainability, and policy integration, with key journals such as *the Journal of Rural Studies and Sustainability (Switzerland)* emerging as leading publication outlets. Highly cited works such as Scoones on sustainable livelihoods (1,202 citations) and Renting on alternative food networks (1,257 citations) have significantly shaped the discourse, while prolific authors like Marsden and Van der Ploeg contribute extensively to rural development and agri-food system research. The analysis of keyword co-occurrence maps underscores an increased interest in technology and environmental sustainability, showing a shift toward digital economy topics and green technology integration. Country-based co-authorship networks reveal extensive collaborations, particularly among the United States, India, and Germany, driven by shared global challenges such as climate resilience and food security. These partnerships facilitate knowledge exchange, advance sustainable agricultural technologies, and influence policy frameworks, highlighting the need for future research to assess their effectiveness in shaping policy decisions and improving technological adoption in rural agricultural systems. This study provides valuable insights for researchers and policymakers, encouraging interdisciplinary approaches to tackle global agriculture and rural development challenges through sustainable and adaptable solutions. The findings underscore the field's responsiveness to emerging issues. They highlight the need for future research to explore interdisciplinary collaborations further, integrate advanced digital technologies in rural sustainability efforts, and develop policy frameworks that enhance the resilience of agricultural communities in the face of climate change and economic shifts.

Keywords: Agricultural technology, rural development, sustainability, rural resilience, climate-smart agriculture, agri-food systems.

INTRODUCTION

Research on agricultural technology and rural development has evolved significantly in recent years to address pressing global challenges such as climate change, food security, and sustainable rural livelihoods. With increasing climate variability and its impact on agriculture, the focus has shifted toward Climate-Smart Agriculture (CSA) as a critical approach to enhancing resilience in farming communities. Studies by Ma and Rahut (2024) emphasize the adoption, impacts, and implications of climate-smart practices for sustainable development, underscoring the need for innovative solutions that strengthen food security while promoting sustainability in agricultural systems. By incorporating climate-resilient practices, CSA aims to help communities mitigate climate impacts and build adaptability, essential for maintaining agricultural productivity and

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ensuring food security in the face of environmental challenges.

The development of net-zero, climate-resilient food systems has become another primary research focus, highlighting the role of innovative agricultural practices and robust policy frameworks in achieving sustainability goals. Given this area's growing body of research, bibliometric analysis is essential to systematically map how these themes have evolved over time, identify key contributions, and assess the extent of interdisciplinary collaboration in shaping sustainable agricultural practices and policies. According to Falloon et al. (2024), strategies to achieve these goals require a comprehensive approach integrating technology, policy, and practice. By fostering innovation and supporting policy initiatives that promote sustainable practices, researchers and policymakers are working to create agricultural systems that reduce carbon emissions and adapt to climate stresses, thus ensuring the longevity and resilience of rural economies (Edi Purwanto & Prasetio, 2021). This aligns with prior studies indicating that standard operating procedures for food safety, such as those for salted fish, will establish the market value of salted fish and the market networks that underpin sustainable business practices (Christian et al., 2024). Furthermore, this focus also on sustainable systems represents a shift towards an integrated approach, where food security and environmental stewardship are pursued in tandem.

Moreover, studies such as those by Areal and Pede (2023) and Gutiérrez Cano et al. (2023) highlight the importance of understanding technology adoption and collaborative efforts among stakeholders. Areal and Pede (2023) discusses how tailored approaches to agricultural technology adoption can lead to more effective outcomes, as various factors—including socioeconomic conditions and regional characteristics—influence adoption decisions. Gutierrez Cano et al. (2023) further emphasize the need for collaboration among stakeholders, training platforms, and innovation processes to foster sustainable agricultural technology and rural development. In parallel, research by Mallappa and Pathak (2023) focuses on small-scale farmers, exploring the awareness, factors, and challenges they face in adopting climate-smart technologies. Together, these studies indicate that achieving food security and sustainable development in rural areas requires technological innovation and a supportive ecosystem that includes stakeholder collaboration, context-specific strategies, and comprehensive policy support.

Despite extensive research in both agricultural technology and rural development, previous bibliometric studies have typically examined these fields separately, focusing either on technological advancements in agriculture (Lee et al., 2012) or rural development trends (Cazorla-Montero & los Ríos-Carmenado, 2023; Muhtar et al., 2023; Singhania et al., 2022; Lu & de Vries, 2021; Kulak, 2018; Knapczyk et al., 2018). However, the increasing convergence of these fields—driven by the need for sustainable farming practices, climate adaptation, and integrated rural policies—necessitates a comprehensive bibliometric analysis that examines their interconnectedness. A combined bibliometric analysis is novel and necessary. It provides a holistic understanding of how agricultural innovations contribute to rural development while revealing the influence of policy frameworks, sustainability considerations, and digital transformations on technology adoption. This approach identifies emerging research trends, key contributors, and collaborative networks, offering valuable insights for guiding future interdisciplinary research and policymaking in sustainable agriculture and rural resilience

Applying bibliometric analysis techniques, such as bibliographic coupling and keyword co-occurrence visualization, allows an in-depth exploration of core topics, emerging themes, and collaborative networks within agricultural research. Previous studies have highlighted the importance of interdisciplinary approaches in this field, as rural development spans socio-economic, environmental, and technological domains. However, only some analyses have systematically examined the interconnectedness of research contributions and the evolution of research focus areas over time. This study seeks to address this gap by utilizing Scopus data and advanced bibliometric tools, namely VOSviewer, to identify influential works and visualize thematic networks within the field.

Through this comprehensive bibliometric approach, the study uncovers significant research clusters' focus and shifts over time, offering insights into how the field has expanded from foundational topics in rural sociology and land use to encompass modern challenges in digital technology, sustainability, and global food systems. The findings aim to inform scholars, policymakers, and practitioners about the most impactful research areas and the growing importance of interdisciplinary collaboration in driving sustainable rural development and agricultural innovation.

Historical evolution of agricultural technology and rural development: The evolution of agricultural technology has profoundly shaped rural development, moving from simple, traditional practices to sophisticated innovations focused on sustainability. Initially, agriculture was marked by rudimentary techniques, but transformative events like the Green Revolution spurred a shift towards high-yield varieties and modern farming methods. This progression has been critical in addressing global food security and environmental issues, fostering a more comprehensive approach to rural development, and considering productivity and ecological balance.

Agricultural practices have developed over thousands of years, originating from hunter-gatherer communities and advancing toward settled farming, which significantly increased productivity and supported the growth of urban centers (Lauvergne, 2017). The Green Revolution, spanning

the 1960s to 1980s, introduced high-yield crop varieties and chemical fertilizers, dramatically boosting food production and sparing millions of hectares from further agricultural expansion (Stevenson et al., 2013). This period marked a pivotal shift toward productivity-focused agriculture, setting the foundation for future technological advances in farming.

As the agricultural sector moved into the "Gene Revolution," the emphasis shifted towards biotechnology, with innovations like CRISPR and genome editing enhancing crop resilience and yield to address climate change (M. F. Hamdan et al., 2022). Contemporary agricultural policies increasingly align with sustainable development goals, emphasizing improved nutrition, ecosystem health, and the revitalization of rural communities (Caron et al., 2018). This shift highlights a broader recognition of agriculture's role in sustainable development, where the focus extends beyond productivity to include environmental sustainability and community well-being.

Global initiatives, such as the Alliance for a Green Revolution in Africa (AGRA), work to empower small-scale farmers by improving access to resources and markets, addressing food insecurity and poverty (Toenniessen et al., 2008). These programs represent a historical shift in agricultural policy toward sustainable practices that balance high productivity with environmental care. Despite these advancements, concerns remain about socio-economic disparities that may arise due to unequal access to these technologies. There is a risk that such inequalities could exacerbate existing divides in rural areas, underscoring the need for inclusive policies to ensure that all communities benefit from technological progress in agriculture. This history illustrates that while technological advances have significantly supported rural development, addressing socio-economic disparities is crucial to ensure that the benefits of these innovations are accessible to all.

***Climate-smart agriculture and sustainability*:** CSA practices are increasingly valued for their role in enhancing resilience and sustainability within rural farming systems, especially as they face the pressures of climate change. Research highlights that CSA boosts agricultural productivity and strengthens rural livelihoods by addressing food security and income stability. Recent studies emphasize CSA's impact on resilience and sustainability, underscoring its transformative potential for rural farming communities. CSA practices like crop diversification and agroforestry have proven effective in increasing productivity and income. For example, farmers in Ethiopia who adopted these practices reported an average annual revenue per hectare that was 20.3% higher than that of non-adopters, illustrating CSA's potential to substantially improve farm profitability (Belay et al., 2024). Additionally, CSA adoption correlates positively with food security, as reflected in improved food consumption scores and increased households meeting acceptable food consumption standards (Belay et al., 2024). These practices also build climate resilience; innovations such as improved crop varieties and advanced soil management techniques empower farmers to better adapt to climate stresses, enhancing their capacity to withstand adverse conditions (Teklu et al., 2023). Furthermore, other pertinent sectors, like enterprises that produce salted fish from catches by fishermen (Christian, Dewantara, Yulita, Sunarno, et al., 2024) and those cultivating fresh or ornamental flowers (Christian, Rembulan, Sugiyanto, Yulita, et al., 2024), are intricately linked to management practices associated with climate and sustainability.

CSA practices support adaptation to climate change and help mitigate greenhouse gas emissions, thereby addressing both sides of the climate challenge (Edi Purwanto et al., 2023). By promoting sustainable agricultural methods, CSA contributes to lower GHG emissions while maintaining productivity (Ma & Rahut, 2024; Zhao et al., 2023). Policy support is critical for scaling up CSA, with effective extension services and sound policies playing essential roles in enabling farmers to adapt while contributing to carbon reduction efforts (Belay et al., 2024; Sisay et al., 2023). Despite the promise of CSA practices, barriers remain to their widespread adoption, including limited access to resources and information. Overcoming these challenges is essential to fully realize CSA's potential to build resilience and sustainability in rural farming systems.

***Role of policy and collaboration in technology adoption*:** Policy frameworks and collaborative efforts among stakeholders greatly shape the adoption of agricultural technology in rural areas. Together, these can enhance technology uptake among small-scale farmers. Research indicates that tailored approaches addressing socio-economic conditions are essential in driving adoption rates across diverse regions, making technological integration in agriculture more effective and inclusive. Policy instruments, such as subsidies, targeted training programs, and secure land rights, are pivotal in encouraging smallholders to adopt CSA practices (van Asseldonk et al., 2023). Support mechanisms like establishing test plots and offering hands-on knowledge training can also increase farmers' willingness to engage with smart agriculture technologies (Li et al., 2023). These policy-driven initiatives provide resources and assurance that small-scale farmers need to explore and integrate innovative agricultural practices.

Socio-economic factors, including education and income levels, strongly influence technology adoption. Studies show that farmers with higher education levels and annual income are more likely to be aware of and adopt climate-smart technologies (Mallappa & Pathak, 2023). Access to information also plays a crucial role; participation in agricultural extension programs and exposure to agricultural media significantly impact farmers' adoption decisions, underscoring the importance of knowledge dissemination in the adoption process (Mallappa & Pathak, 2023).

Effective adoption strategies must account for regional contexts, as land availability and capital constraints affect technology uptake differently across regions (Schulz & Börner, 2023). Strengthening agricultural knowledge and innovation systems is essential to bridge the gap between the potential for technology adoption and its actual implementation in the field (Masi et al., 2022). These tailored approaches allow for a more responsive adoption strategy that respects local conditions and empowers farmers accordingly. While supportive policies and collaborations are crucial, barriers such as high input costs and limited access to information continue to challenge adoption, particularly for marginalized farmers. Overcoming these barriers is essential for achieving widespread technology integration and realizing the benefits of agricultural advancements across rural communities.

***Digital economy and technological advancements*:** The expanding role of digital innovations, particularly in the digital economy and e-governance, is instrumental in advancing rural development and bridging the rural-urban divide. These technologies are transforming rural economies by enhancing market access, improving agricultural practices, and promoting economic growth. Digital platforms give farmers access to broader markets, bypassing intermediaries, increasing their income, and reducing post-harvest waste (Altarturi et al., 2023; Purwanto et al., 2023). E-governance initiatives further enhance rural livelihoods by streamlining access to essential public services, improving the efficiency and reach of healthcare and other critical services in remote areas (X. Zhao et al., 2024). These digital advancements contribute to a more connected and resourceful rural landscape. Information and communication technology (ICT) tools are vital in supporting the agricultural value chain, from production to marketing. ICT facilitates better resource allocation, reduces labor misallocation, and helps farmers optimize processes across the value chain (Jia, 2023). Programs such as Digital India have shown that increasing digital literacy, particularly among women, promotes higher technology adoption rates, leading to economic empowerment and increased productivity (Sindakis & Showkat, 2024).

The digital economy reduces income disparities between urban and rural areas, fostering more balanced economic development (Cheng & Zheng, 2023). While eastern regions benefit more from digital advancements, central and western areas also experience positive impacts, albeit on different scales (Cheng & Zheng, 2023). This regional variability highlights the need for targeted approaches to maximize digital benefits across diverse rural contexts. Although digital innovations hold tremendous potential for rural development, infrastructure deficits, and digital literacy gaps persist as barriers to equitable benefits. Addressing these obstacles is essential to ensure that all rural communities can fully participate in and benefit from the digital economy.

***Socio-economic and environmental dimensions of rural development*:** Rural communities encounter significant socio-economic challenges, such as poverty alleviation, migration, and social planning, that are deeply intertwined with environmental concerns. Research underscores the importance of enhancing public services and economic vitality to attract and retain residents, mainly as rural in-migration is influenced by factors like education opportunities and the quality of the natural environment (Li et al., 2024). Additionally, community-led initiatives targeting health issues, such as obesity prevention among rural preschoolers, highlight the need for improved food security and access to recreational facilities, illustrating the connection between health and socio-economic factors (Pope et al., 2024).

Rural areas often face slower economic development when addressing poverty alleviation, making targeted economic interventions essential to stimulate local growth (Mahon et al., 2023). Migration trends reveal that access to quality public services is a key factor in settlement decisions, particularly for educated individuals who value strong healthcare, educational, and infrastructure systems (Li et al., 2024). Social planning is also vital, as effective governance and community engagement are crucial for addressing local needs and fostering social equity (Lin, 2024). Sustainable land use is essential for maintaining the health of rural landscapes and ecosystem services, supporting the long-term viability of these communities (Labianca, 2023). Additionally, improved governance can lead to better waste management practices, enhancing environmental quality and livability (Lin, 2024). Adopting renewable energy is another critical area, as integrating sustainable energy solutions can reduce rural dependency on non-renewable resources, fostering environmental sustainability (Mahon et al., 2023). While addressing these socio-economic and environmental dimensions is essential, rural areas also offer significant potential for innovation and adaptation through community-led initiatives. These initiatives can sometimes lead to unexpected positive outcomes, demonstrating that rural communities can drive meaningful progress across socio-economic and environmental fronts.

MATERIALS AND METHODS

This study utilizes a bibliometric analysis to examine the evolution of agricultural technology and rural development research, identifying influential works, key research themes, and trends. Data were sourced from the Scopus database, which provides a vast repository of academic literature suitable for studying trends across disciplines. Using the keywords “agricultural technology” and “rural development,” we initially retrieved 5,961 documents related to these fields.

Table 1. Documents by type.

Documents	Type
Article	4355
Book Chapter	581
Conference Paper	476
Review	229
Book	116
Conference Review	71
Editorial	56
Note	29
Erratum	19
Letter	11
Short Survey	8
Retracted	7
Data Paper	2
Report	1
Total	5961

To ensure that the analysis focused on primary research and substantial academic contributions, certain document types were excluded. Specifically, we removed reviews, books, conference reviews, editorials, notes, errata, letters, short surveys, retracted papers, data papers, and reports, as these formats often do not provide primary research data or foundational studies. This filtering resulted in a final dataset of 5,412 documents comprising articles, book chapters, and conference papers formats typically containing original research, in-depth analysis, or substantial contributions to the field. VOSviewer software was employed for the bibliometric analysis to construct visual networks, including bibliographic coupling networks, co-authorship networks, and keyword co-occurrence maps (Edi Purwanto & Irawan, 2023). These visualizations facilitated an exploration of the interconnections among key topics, authors, and journals. Keyword co-occurrence analysis allowed for identifying high-frequency terms and emerging research themes (Pitaloka et al., 2024). Additionally, by tracking shared references, bibliographic coupling provided insight into the relationships among influential journals, authors, and publications (Dwianika et al., 2024). These methods offer a comprehensive view of the primary focus areas and evolving research trends within agricultural technology and rural development.

Table 2. Documents by type.

Documents	Type
Article	4355
Book Chapter	581
Conference Paper	476
Total	5412

Figure 1 illustrates the systematic process of conducting a bibliometric analysis of agricultural technology and rural development.

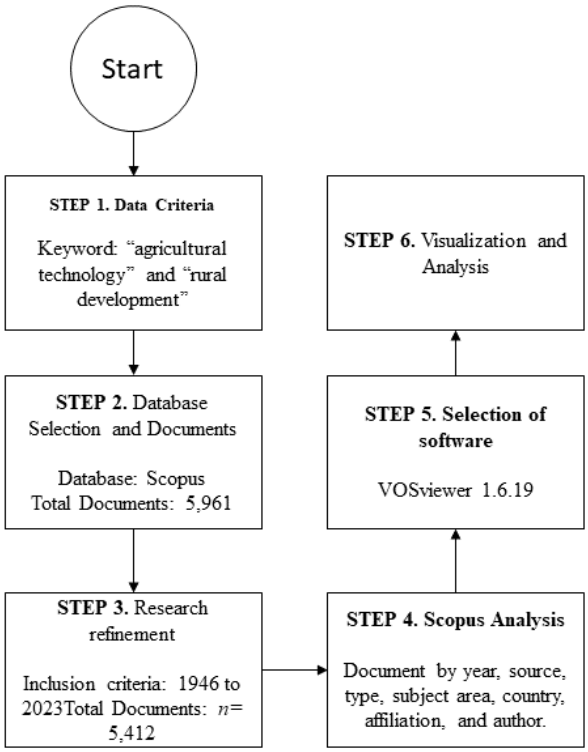
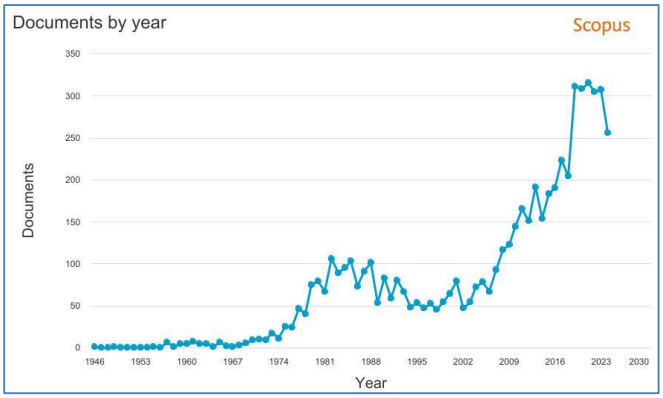

Start
STEP 1. Data Criteria
Keyword: "agricultural technology" and "rural development"
STEP 2. Database Selection and Documents
Database: Scopus
Total Documents: 5,961
STEP 3. Research refinement
Inclusion criteria: 1946 to 2023Total Documents: n= 5,412
STEP 4. Scopus Analysis
Document by year, source, type, subject area, country, affiliation, and author.
STEP 5. Selection of software
VOSviewer 1.6.19
STEP 6. Visualization and Analysis

Figure 1. Research methodology flowchart.

RESULTS

The publication trends in agricultural technology and rural development: The Publication Trends in Agricultural Technology and Rural Development, as in Figure 2, illustrates the evolution of research output in these fields from 1946 to 2023, highlighting different phases that reflect historical and scientific developments. From 1946 to the early 1970s, publication activity remained minimal, with only a few documents published yearly. This period likely marks the foundational years of research in agriculture and rural development, where the focus was primarily on basic agricultural practices and early rural policies. Technological advancements were limited, and the integration of technology in agriculture was still in its infancy, resulting in relatively low scholarly interest and publication output. In the 1980s, publication output rose, fluctuating through the 1990s and early 2000s. This growth coincides with the global recognition of food security, poverty alleviation, and the need for rural development, influenced by events like the Green Revolution and international efforts to improve agricultural productivity. Although there were inconsistencies in publication counts, the overall upward trend reflects a growing interest in applying technology to farming and rural challenges. During this time, research also focused more on the environmental impacts of agriculture and the socio-

economic challenges rural communities face, setting the stage for more sustained growth in the following decades.



Source: Scopus Database

Figure 2. Publication trends in agricultural technology and rural development.

A sharp increase in publication activity started around 2010, peaking between 2016 and 2020. This surge reflects an intensified global focus on sustainable agriculture, digital innovation, and the modernization of rural economies, driven by concerns about climate change, food security, and rural poverty. The alignment with the United Nations' Sustainable Development Goals (SDGs), prioritizing sustainable agriculture and improved rural livelihoods, likely contributed to this rise. The slight decline after 2020 might indicate a stabilization in research output or shifts in funding priorities, though interest in these fields remains strong. This trend highlights the transition of agricultural technology and rural development into highly interdisciplinary areas, critical for addressing modern global challenges and shaping future research agendas.

***Bibliographic coupling network of agricultural technology and rural development research journals*:** The Bibliographic Coupling Network in the provided Figure 3 offers a detailed look at the interconnections among journals in agricultural technology and rural development. At the core of this network, journals like the Journal of Rural Studies**,** Sustainability (Switzerland)**,** Land Use Policy**,** Community Development Journal, and the American Journal of Agriculture emerge as significant nodes. Their central position and dense connections reflect the high frequency of shared citations, indicating that these journals serve as foundational resources within this field. They cover a broad range of topics, from rural development policies to sustainable land use practices, which makes them pivotal to academic conversations in agricultural technology and rural studies.

The Journal of Rural Studies appears as a primary hub in this network, underscoring its interdisciplinary approach to rural sociology, economic impacts of agricultural practices, and community-based development. The journal's central role highlights its frequent citation alongside other journals that focus on community development and sustainability, establishing it as an anchor for studies related to the socio-economic dynamics of rural areas. Meanwhile, Sustainability (Switzerland) is closely connected to journals covering rural

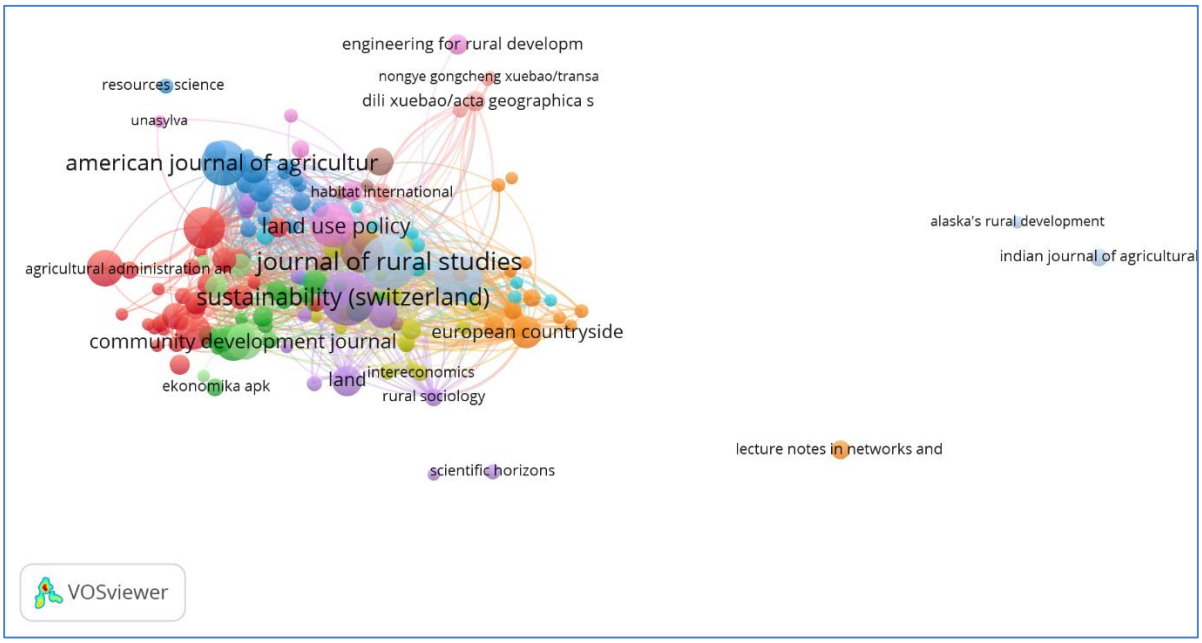


Figure 3. Bibliographic coupling network of agricultural technology and rural development research journals.

studies and land use, focusing on sustainable agricultural and development practices. This journal likely emphasizes environmental impacts, sustainable farming practices, and resilience strategies for rural communities facing climate and resource challenges. Similarly, Land Use Policy is critical in the network, emphasizing how land management practices and policies influence rural development and agricultural innovation. Its connections with journals like the Journal of Rural Studies and Sustainability suggest a strong relationship between agricultural technology and land use policies in supporting sustainable rural growth.

Distinct clusters within the network reflect thematic groupings among the journals. In the blue cluster (e.g., American Journal of Agriculture**,** Resource Science**)**, journals likely focus on agricultural science, resource management, and the technical aspects of agricultural technology. These journals cover advancements in farming techniques, resource optimization, and the scientific basis for enhancing agricultural productivity. The red cluster (e.g., Agricultural Administration**,** Community Development Journal**)** emphasizes administrative, policy, and community-based research. Journals here likely explore governance, rural policy, and community-centered approaches to development, illustrating how administrative frameworks and local engagement contribute to rural sustainability. The green cluster (e.g., Rural Sociology**,** Community Development Journal) focuses on sociological aspects of rural development, examining social dynamics, rural livelihoods, and the effects of technological change on rural communities. This cluster's inclusion of Rural Sociology highlights the importance of social sciences in understanding the broader impacts of agricultural advancements. Finally, the orange cluster (e.g., European Countryside**,** Habitat International) includes journals that may focus on rural development within specific geographical contexts, such as Europe. European Countryside is prominent here, indicating that regional journals provide valuable localized insights that complement broader, more general publications.

The network also contains peripheral journals, such as Alaska's Rural Development**,** Indian Journal of Agriculture**,** and Lecture Notes in Networks and Systems, which are relatively isolated from the main clusters. These journals likely cover specialized or region-specific agricultural technology and rural development aspects that are not as widely referenced. For instance, Alaska's Rural Development might explore issues unique to Alaska, such as indigenous land rights, local governance, and resource management in cold climates. Indian Journal of Agriculture may address agricultural challenges specific to India, focusing on tropical farming, smallholder farming technologies, and food security in South Asia. Lecture Notes in Networks and Systems suggest a technical focus on network analysis, systems modeling, and data-driven innovations in agricultural practices, indicating a unique intersection of technology and rural studies.

This concentration around core themes, with fewer connections to region-specific or specialized journals, suggests strengths and potential research gaps in the field. The well-represented areas of sustainability, land use policy, and rural sociology reflect a solid research foundation. However, the relative isolation of certain regional journals highlights opportunities to broaden the discourse by integrating more localized studies, offering diverse perspectives that address unique challenges rural communities face.

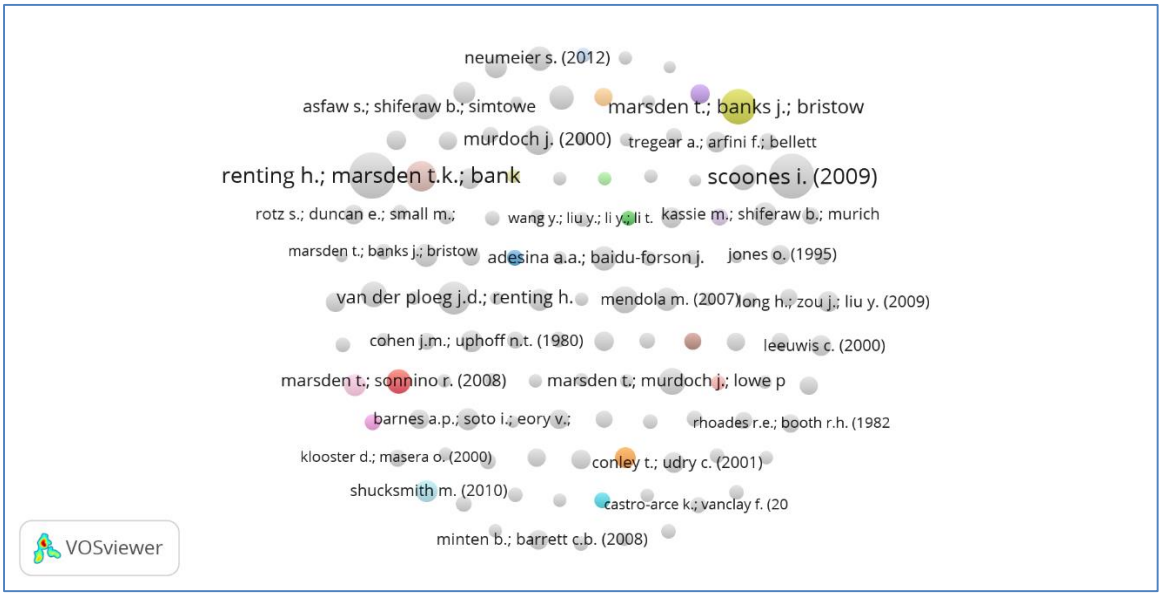

neumeier s. (2012)
asfaw s.; shiferaw b.; simtowe
marsden t.; banks j.; bristow
murdoch j. (2000)
tregear a.; arfini f.; bellett
renting h.; marsden t.k.; bank
scoones i. (2009)
rotz s.; duncan e.; small m.;
wang y.; liu y.; li y.; li t.
kassie m.; shiferaw b.; murich
marsden t.; banks j.; bristow
adesina a.a.; baidu-forson j.
jones o. (1995)
van der ploeg j.d.; renting h.
mendola m. (2007)
long h.; zou j.; liu y. (2009)
cohen j.m.; uphoff n.t. (1980)
leeuwis c. (2000)
marsden t.; sonnino r. (2008)
marsden t.; murdoch j.; lowe p
barnes a.p.; soto i.; eory v.;
rhoades r.e.; booth r.h. (1982
klooster d.; masera o. (2000)
conley t.; udry c. (2001)
shucksmith m. (2010)
castro-arce k.; vanclay f. (20
minten b.; barrett c.b. (2008)
VOSviewer

Figure 4. Citation map of influential authors and publications.

The bibliographic coupling network is a valuable tool for researchers and practitioners. Central journals serve as primary resources for comprehensive, interdisciplinary research, while journal clustering can guide researchers in selecting sources based on specific themes or regional interests. This network also offers a roadmap for interdisciplinary collaboration, encouraging researchers to engage in adjacent fields to enrich their understanding and broaden the relevance of their work.

The Bibliographic Coupling Network illustrates the interconnected landscape of agricultural technology and rural development research. Core journals like the Journal of Rural Studies**,** Sustainability (Switzerland), and Land Use Policy anchor the field, supported by thematic clusters that address diverse dimensions of rural development. While this network reflects a robust research base, peripheral journals indicate opportunities for expanding the discourse to include more region-specific and technical studies, fostering a richer, more inclusive understanding of rural development and agricultural technology.

***Citation map of influential authors and publications*:** The citation map (Figure 4) and data (Table 3) on influential publications reveal vital authors and works shaping agricultural technology and rural development research. The highest-cited works, such as those by Renting et al. (2003) and Scoones (2009), with 1,257 and 1,202 citations, respectively, highlight the prominence of sustainability and resilience as central themes in this field. Scoones (2009) is mainly known for his contributions to sustainable livelihoods, emphasizing adaptive strategies that rural communities use to navigate environmental and economic changes. Renting's work aligns with this focus, exploring sustainable rural development and how agriculture contributes to community resilience.

Table 3. Top 10 publications on agricultural technology and rural development with the highest citations in Scopus.

No.	Author/ References	Year	Citations
1	Renting *et al.* (2003)	2003	1257
2	Scoones (2009)	2009	1202
3	Terry Marsden *et al.* (2000)	2000	750
4	Van Der Ploeg *et al.* (2000)	2000	640
5	Salemink *et al.* (2017)	2017	543
6	Murdoch (2000)	2000	514
7	Key and Runsten (1999)	1999	433
8	T Marsden *et al.* (1993)	1993	420
9	Ray (1998)	1998	401
10	Abebaw and Haile (2013)	2013	397

Source: Scopus Analyze

Terry Marsden *et al.* (2000) are a recurring and influential figure, with multiple highly cited publications from different years, notably 2000 (750 citations) and 1993 (420 citations). Marsden's research has had a long-lasting impact, likely focusing on rural sociology and the socio-economic dynamics within agricultural systems. Other key figures, such as Der Ploeg et al. (2000) and Murdoch (2000), contribute significantly, with 640 and 514 citations, respectively. These authors likely explore themes related to rural livelihoods, agricultural change, and the social impact of technology, reflecting an interest in the broader socio-economic landscape of rural development.

Several dominant themes emerge in this body of research. Sustainability and rural resilience are underscored by the works of Scoones (2009) and Renting et al. (2003), indicating a strong focus on the durability of rural livelihoods amid challenges. Sociological and economic implications of agricultural technology are also prominent, with authors like Marsden et al. (1993) and Van Der Ploeg et al. (2000) examining how technological advancements reshape rural social structures and economies. Additionally, globalization's impact on rural communities is another essential area of study, with Key and Runsten (1999) and Murdoch (2000) exploring how global market forces affect local rural dynamics and adaptation strategies.

More recent studies indicate an evolving focus in rural development research. Salemink et al. (2017), with 543 citations, appear to examine digital and technological advancements in rural areas, perhaps addressing the digital divide and its consequences for agricultural development. Abebaw and Haile (2013), another recent influential publication, likely discusses contemporary challenges in rural areas of developing countries, such as poverty alleviation, food security, and resource management, reflecting a growing concern with socio-economic development alongside agricultural technology.

The citation map visually groups interconnected authors, showing thematic clusters. For instance, Renting, Marsden, and Van Der Ploeg appear closely related, suggesting that their research centers on rural sociology and agricultural technology. Similarly, Scoones and Murdoch form another cluster, which may indicate a shared interest in sustainable livelihoods and rural adaptation strategies. Surrounding these core authors are less cited but relevant works, contributing additional perspectives that enrich the discourse on rural development and technological integration.

Analyzing the timeline of these influential works shows a shift from foundational studies in the 1990s, like those by Key and Runsten (1999) and Marsden (1993), toward addressing contemporary issues such as digital access (Salemink et al., 2017) and sustainable livelihoods (Scoones, 2009). This evolution suggests that rural development research has progressively expanded from traditional agricultural and socio-economic concerns to modern challenges associated with technology and globalization.

The citation map and top publications reflect a research landscape shaped by foundational authors like Marsden,

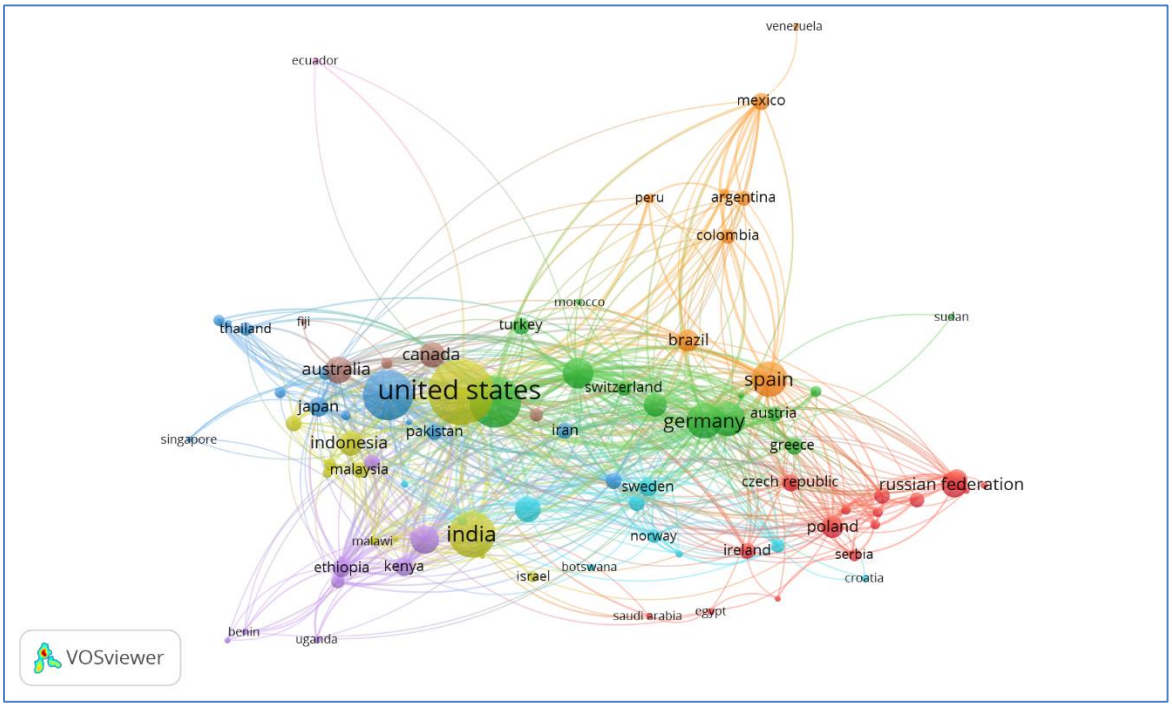


Figure 5. Co-authorship network by country.

Scoones, and Renting, whose work set the theoretical and practical directions for the field. Their contributions are complemented by recent studies addressing emerging technology and rural resilience challenges. Together, these classic and contemporary perspectives create a rich, evolving discourse on the interplay between agricultural technology, rural development, and community adaptation in a rapidly changing world.

***Co-authorship network by country*:** The Co-authorship Network by Country in agricultural technology and rural development, as shown in Figure 5, reveals significant collaborative relationships, with the United States standing out as a dominant hub. Its extensive connections highlight the U.S.'s leading role in global research partnerships, especially in sustainable agriculture and rural development. Other key players, such as India and Germany, also show substantial co-authorship links, reflecting their active involvement in international research. India's prominence underscores its focus on agricultural innovation, crucial for its agrarian economy, while Germany's strong presence aligns with its research on sustainable practices and rural policy. Countries like Spain, China, and Australia are also notable contributors, with their partnerships emphasizing global research themes, such as food security, climate resilience, and technology transfer for rural communities.

The network reveals distinct regional clusters that shape research collaborations. North America forms a cluster focused on shared agricultural challenges and sustainable practices with the U.S., Canada, and Mexico. In contrast, Europe's cluster, including Germany, Spain, and the U.K., reflects the collaborative efforts of EU-funded initiatives. Latin American countries like Brazil, Argentina, and Colombia show regional partnerships centered on sustainable development and agriculture for economic stability. The Asia-Pacific cluster, involving India, China, and Japan, focuses on productivity and technological advancements in agriculture. Meanwhile, African countries such as Ethiopia, Kenya, and Uganda are forming smaller clusters, mainly driven by collaborations focused on food security and rural resilience. These clusters highlight how geographical proximity and share regional challenges foster collaborations that address local and global agricultural issues.

Bridging countries, such as Mexico and Turkey, play a vital role by linking different clusters and facilitating cross-regional research dissemination. Mexico connects North and Latin America, promoting knowledge sharing across these regions, while Turkey bridges Europe and Asia, reflecting its strategic position in agricultural and water management studies. Countries like Canada and Australia maintain connections across multiple clusters, highlighting their contributions to global research on climate resilience and agricultural innovation. For emerging economies, especially those in Africa, strengthening direct research collaborations within their region could enhance regional knowledge sharing and reduce reliance on external partnerships. The network underscores the importance of regional alliances and bridging

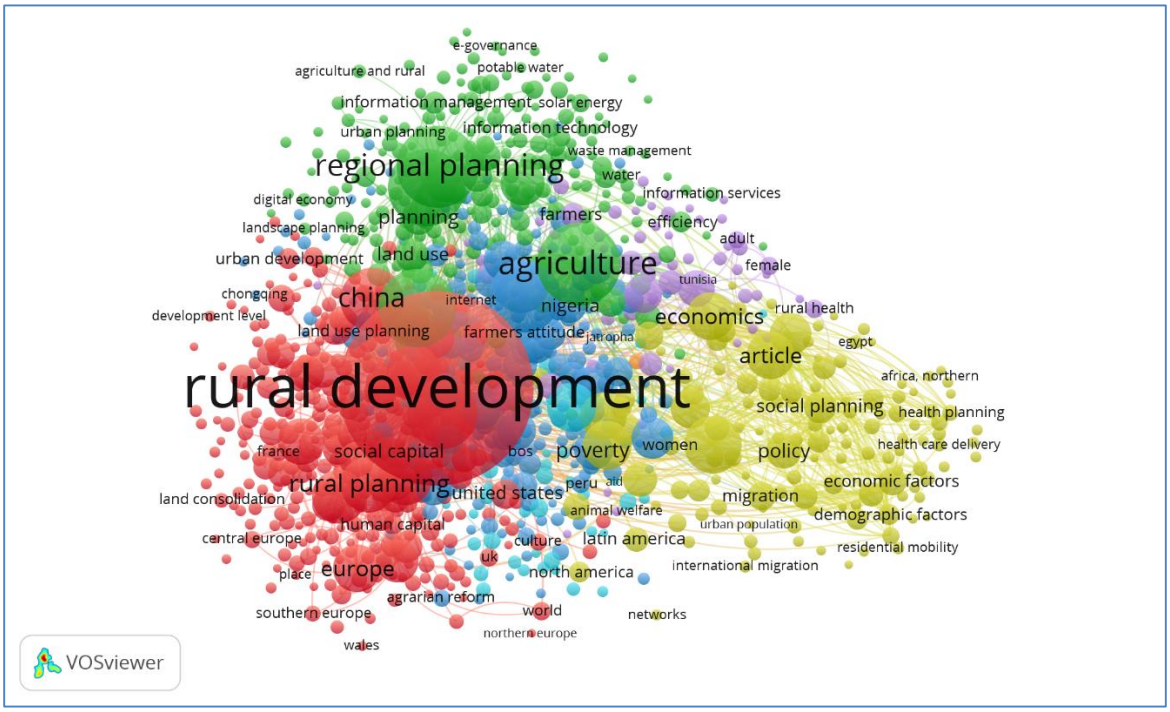


Figure 6. Network visualization co-occurrence all keyword.

countries to foster a global approach to agricultural technology and rural development challenges.

***Co-occurrence network of keywords in agricultural technology and rural development research*:** The Network Visualization of Keyword Co-occurrence, as in Figure 6, reveals the thematic structure of research in agricultural technology and rural development, with central themes such as "rural development," "regional planning," and "agriculture" dominating the network. Supporting clusters surround these themes, each representing a different aspect of rural development research. The central keyword, "rural development," is the most significant node, reflecting its foundational role in the field and frequent co-occurrence with other terms. Surrounding this core are keywords like "social capital," "poverty," "rural planning," and "land use planning," which suggest that the field emphasizes the socio-economic dimensions of rural communities. Terms like "China" and "Europe" also appear within this cluster, indicating that region-specific studies are a significant part of the discourse on rural development.

Several clusters emerge within the network, each highlighting a specific thematic area within rural development. The red cluster centers on "rural development," "social capital," and "human capital," incorporating terms like "rural planning," "Europe," and "agrarian change." This cluster suggests a focus on rural life's socio-economic and community aspects, including rural planning, regional case studies, and the role of social and human capital in development. The green cluster organized around "regional planning," "land use planning," and "urban planning," highlights a focus on spatial and environmental aspects of development. Keywords in this cluster, such as "information technology," "waste management," and "solar energy," point to an interest in sustainable practices and technologies that support integrated rural and urban growth, emphasizing the role of planning in environmental management and resource allocation.

The yellow cluster is centered around "economics," "policy," and "demographic factors," including terms like "migration," and "social planning." This grouping emphasizes economic policies and demographic challenges in rural areas, such as poverty reduction, migration management, and access to social services. Keywords such as "health planning," "policy," and "economic factors" reflect the influence of social policies on rural development, underscoring the importance of integrating economic analysis with social planning to address complex rural issues. Lastly, the blue cluster revolves around "agriculture" and includes terms like "farmers," "land use planning," "agriculture policy" and "rural development project," pointing to the foundational role of agriculture in rural development. This cluster's focus includes optimizing agricultural practices, improving land use efficiency, and understanding farmer attitudes toward policies.

The co-occurrence of keywords like "rural development" and "poverty" highlights the socio-economic focus of much research in this field, reflecting a strong emphasis on how

rural development strategies can alleviate poverty and improve the quality of life in rural areas. Integrating terms such as "migration" and "policy" in the economics cluster further underscores the role of migration patterns and policy interventions in shaping rural demographics and economic stability. Additionally, connections between "regional planning" and sustainability-related terms like "solar energy" and "waste management" suggest a growing interest in environmental sustainability and green technologies in rural contexts. This indicates that researchers are increasingly considering how innovative, eco-friendly technologies can support rural and regional development, balancing growth with environmental protection. The presence of region-specific terms, including "China," "Nigeria," and "Latin America" within different clusters, highlights the global scope of rural development research. Regional studies are essential for understanding how unique socio-political and economic contexts shape rural development outcomes. The structure of the network, with regional terms interwoven across clusters, suggests a need for both localized approaches and cross-regional comparisons in addressing rural development challenges. This Network Visualization of Keyword Co-occurrence reflects the comprehensive and interdisciplinary nature of agricultural technology and rural development research, blending socio-economic, environmental, and technological insights to tackle the complex priorities and challenges in improving rural life.

***Temporal evolution of keyword co-occurrence*:** The Temporal Evolution of Keyword Co-occurrence in agricultural technology and rural development, as in Figure 7, highlights the shifting priorities of research over the past two decades. In the early 2000s, themes such as "rural development," "social capital," "land use planning," and "regional planning" dominated the field, as indicated by the blue and green hues in the network. These foundational areas reflected a focus on socio-economic challenges, with a significant emphasis on understanding the role of social structures and regional planning in supporting rural growth. Research during this period frequently addressed issues related to "land consolidation," "agrarian reform," and "urban planning," particularly in regions experiencing rapid urbanization. Geographically, much of this research focused on specific areas like "Europe," "China," and "Latin America," aiming to understand how socio-economic transitions in these areas could shape rural development.

Between 2010 and 2015, research themes began to broaden, shifting towards economic dimensions and agricultural sustainability, as indicated by keywords like "agriculture," "poverty," "policy," and "economics." Agriculture became a central theme during this period, reflecting an increased focus on the role of agricultural practices in rural economies and livelihoods. This research phase also delved into "poverty" and "economic factors," examining how economic disparities could be addressed to support sustainable rural development. Additionally, the presence of terms such as "health planning,"

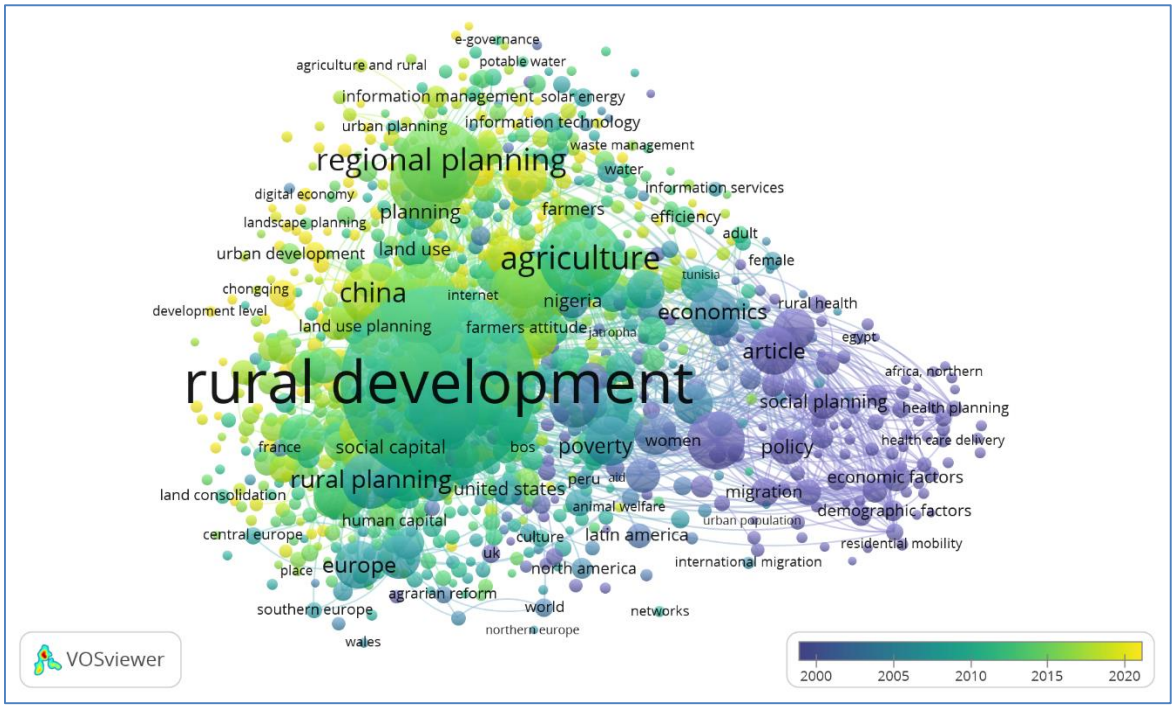


Figure 7. Temporal evolution of keyword co-occurrence.

"migration," and "policy" reveals an emerging interdisciplinary approach as researchers incorporate demographic and social factors into rural development studies. The keyword "migration" highlights attention to rural-to-urban migration and its impact on rural labor markets, while "health planning" underscores the growing interest in healthcare access for rural populations.

In recent years (2015-2020), as shown by the yellow and light green nodes, the focus of rural development research has increasingly shifted towards technology and sustainability. Terms like "information technology," "solar energy," "digital economy," and "e-governance" reflect a forward-looking approach where technological innovation is seen as key to addressing modern rural challenges. This period also emphasizes environmental sustainability, with keywords such as "waste management" and "solar energy" pointing to research on renewable resources and efficient resource management (Edi Purwanto et al., 2024). The inclusion of "farmers' attitudes," "internet," and "information services" suggests a strong interest in the role of digital technology in enhancing agricultural practices and improving rural economies. This shift toward integrating technology and sustainability into rural development reflects the field's responsiveness to global challenges like climate change, resource scarcity, and digital inclusion, showcasing a holistic approach that now considers technological, environmental, and socio-economic dimensions of rural resilience.

***Density visualization of research focus areas*:** The Density Visualization of Research Focus Areas, as in Figure 8, highlights the core themes and concentrations within agricultural technology and rural development research. At the center of the visualization, "rural development" emerges as the most densely clustered term, underscoring its foundational role in the field. Surrounding this core are high-density terms like "social capital," "regional planning," "agriculture," and "rural planning," which indicate the field's focus on socio-economic and spatial aspects of rural growth. Terms such as "social capital" and "human capital" suggest that much research emphasizes the importance of community resources, networks, and local capacities in promoting rural development. Additionally, "agriculture" and "regional planning" reflect a strong interest in how agricultural practices and strategic planning support rural economies, while terms like "China," "Europe," and "Latin America" indicate a regional focus on rural development across different geographic and policy contexts. On the periphery of the visualization, emerging themes such as "information technology," "e-governance," "solar energy," and "digital economy" indicate a shift towards technological and environmental solutions in rural development. "Information technology" and "e-governance" reflect a growing interest in digital tools to improve governance and information access in rural areas. At the same time, "solar energy" and "waste management" suggest an increasing focus on sustainable practices. These keywords highlight the recent emphasis on

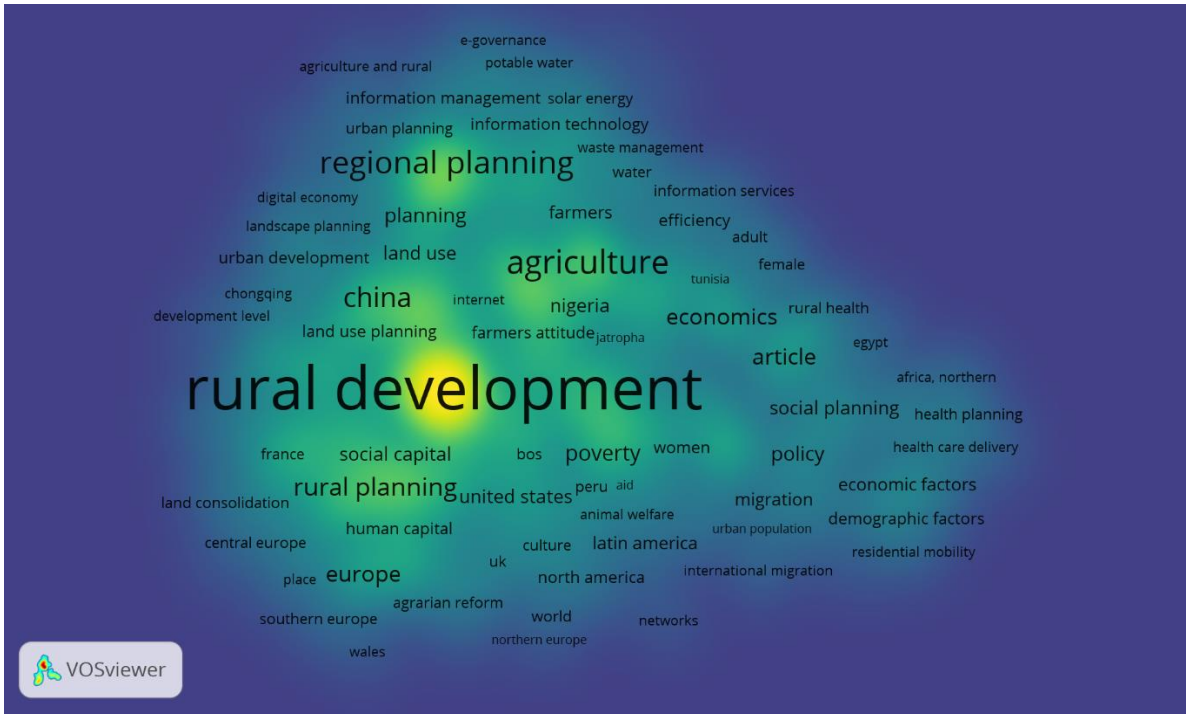


Figure 8. Density visualization of research focus areas.

using technology to address environmental challenges and bridge the digital divide in rural communities. This evolving interest in digital and environmental solutions indicates a dynamic research landscape that balances traditional socio-economic themes with forward-looking strategies for sustainable rural growth.

DISCUSSION

Each cluster based on the keyword co-occurrence network in agricultural technology and rural development research highlights a distinct yet interconnected theme. These themes reflect a blend of socio-economic, environmental, policy-oriented, and agricultural dimensions essential for addressing modern rural challenges. These themes illustrate the interdisciplinary and global scope of the field, underscoring a comprehensive approach to sustainable and resilient rural growth.

***Red cluster: socio-economic and community dimensions of rural development*:** This cluster focuses on the socio-economic aspects of rural communities, integrating keywords like "rural development," "social capital," "human capital," "rural planning," "Europe," and "agrarian change." It represents research on the roles of social and human capital in enhancing rural development, rural planning practices, and regional case studies, emphasizing how community resources and social networks contribute to sustainable growth and resilience in rural areas.

Social and human capital profoundly shape the socio-economic dimensions of rural development, both of which are essential in fostering community resilience and sustainable growth. Research emphasizes the value of social networks and community resources in strengthening rural planning and development practices across various regions, particularly in areas undergoing agrarian transitions. Social capital, characterized by bonding, bridging, and linking networks, facilitates knowledge exchange and community engagement. In rural area, these forms of social capital support knowledge creation and dissemination, enhancing community resilience and collaboration (Cummings et al., 2019). Interventions that actively mobilize social capital have shown promising outcomes, where structured community engagement, supported by local governments and social entrepreneurs, drives effective development results (Onyx & Leonard, 2010). These findings suggest that strong social networks can amplify local efforts toward sustainable rural development.

Human capital, encompassing skills, education, and cultural values, is closely tied to economic performance in rural areas. Studies highlight a correlation between self-direction values and GDP in European regions, showing that cultural values can significantly impact economic success (Weckroth & Kemppainen, 2016). Recognizing the unique characteristics of rural poverty and social exclusion is crucial for creating targeted, effective interventions, as rural poverty often presents challenges distinct from those in urban settings (Commins, 2004). Addressing these challenges requires a deep understanding of the social dynamics within rural communities, which can enhance policy effectiveness and support more inclusive economic growth.

The shift from agrarian to post-agrarian communities reflects a transformation in rural identity, shaped by local perceptions and inherent knowledge. In Poland, for example, these transitions illustrate how contemporary rural identities influence development strategies and community engagement (Tobiasz-Lis & Wojcik, 2023). As rural communities undergo economic and cultural shifts, understanding these evolving identities becomes essential for effective planning and policy-making that aligns with community values and aspirations. While social and human capital is central to rural development, addressing poverty and social exclusion remains a critical challenge. These obstacles can impede progress, necessitating nuanced, context-sensitive approaches to enable genuinely inclusive and sustainable development in rural areas.

***Green cluster: environmental and spatial planning in rural development*:** The green cluster is centered on "regional planning," "land use planning," and "urban planning" and includes terms like "information technology," "waste management," and "solar energy." This theme highlights spatial planning and environmental management strategies in rural contexts, emphasizing sustainable practices, eco-friendly technology integration, and the interdependence of rural and urban planning. It underscores the importance of planning for resource allocation, environmental protection, and sustainable rural-urban connectivity.

Integrating environmental and spatial planning into rural development is essential for fostering sustainable practices and enhancing rural-urban connectivity. This approach highlights the importance of effective resource allocation, environmental protection, and the incorporation of eco-friendly technologies. Effective land use planning is vital for balancing rural ecological, social, and economic needs (Pan et al., 2021). One approach, the Land use Intensity-restricted Multi-objective Spatial Optimization (LIr-MSO) model, demonstrates how land use can be optimized to meet various, sometimes competing, objectives, ensuring that environmental sustainability is maintained alongside economic development (Pan et al., 2021). Such models allow for more strategic decision-making in land use that can align with sustainable growth goals.

The concept of smart villages, which leverages information and communication technology (ICT), is transforming rural sustainability by addressing local needs through strategic, data-driven planning (Zhang & Zhang, 2020). In Austria, spatial planning laws encourage the integration of renewable energy sources at the local level, aligning municipal plans with national energy objectives (Geissler et al., 2022). This approach improves energy sustainability in rural areas and

strengthens the alignment between local and national environmental goals, creating a cohesive framework for technological integration. Spatial resilience planning is critical for mitigating risks within rural ecological structures, supporting the development of green, livable villages (Zeng et al., 2023). Establishing ecological zones and enhancing water system connectivity are key strategies that promote sustainable rural growth and increase resilience against environmental challenges (Zeng et al., 2023). This environmental concern is exacerbated by the direct influence of climate on fish farming in brackish water and salted fish production in Indonesia, hence necessitating improved water management strategies (Christian, Gularso, Rembulan, Yulita, et al., 2024). This matter pertains to regulated salinity in brackish water, which fosters optimal fish growth crucial for the production of high-quality salted seafood (Christian, Yulita, Gularso, et al., 2024). These measures ensure that rural development remains ecologically viable, contributing to long-term ecological health and community well-being. While the focus on sustainable practices is paramount, significant challenges remain, including bureaucratic barriers and the need for comprehensive stakeholder engagement. These obstacles highlight the importance of collaborative, multi-stakeholder approaches to successfully implement sustainable rural planning initiatives.

***Yellow cluster: economic and policy-oriented aspects of rural development*:** Keywords such as "economics," "policy," "demographic factors," "migration," and "social planning" define this cluster, indicating a focus on economic policies and demographic challenges. Research here examines poverty reduction strategies, migration trends, and the role of economic and social policies in addressing rural issues. The theme emphasizes the importance of integrating economic analysis with social planning to tackle complex rural problems, especially migration, poverty, and access to social services.

Rural development is closely intertwined with economic policies and demographic factors, particularly poverty reduction and migration management. Addressing these challenges effectively requires an integration of economic analysis with social planning. This synthesis examines the multifaceted nature of poverty, the impacts of demographic shifts, and the complex role migration plays in rural development. Poverty in rural areas is a multifaceted issue that extends beyond income levels to include health, education, and living standards (Fahad et al., 2023). Addressing rural poverty demands a comprehensive approach, as captured by the sustainable livelihood framework, which evaluates poverty across various dimensions. For example, studies in Vietnam have shown that rural households often lack sufficient natural, social, and financial capital, highlighting critical areas where targeted interventions are needed to improve livelihoods and resilience (Fahad et al., 2023). This multidimensional approach provides a deeper understanding of rural poverty and informs the development of more effective policies and support programs.

Demographic transitions have profound implications for economic growth and rural development policies. As fertility rates decline, the potential for economic prosperity generally increases, creating a cycle that can contribute to poverty reduction (Ranganathan et al., 2015). Policymakers can use models that account for demographic changes to set realistic development goals and monitor the progress of initiatives like the Sustainable Development Goals (SDGs). Recognizing the patterns and impacts of demographic transitions allows governments to allocate resources better and implement policies that support long-term economic stability and growth in rural areas.

Migration is a potential strategy for poverty alleviation, as it allows individuals to seek better opportunities and improve their livelihoods. However, the effectiveness of migration as a poverty reduction tool can vary significantly based on the socio-economic backgrounds of the migrants (Sabates-Wheeler et al., 2008). Ethical considerations also arise concerning the use of immigration policies to address poverty, emphasizing ensuring that migration is voluntary rather than forced. While migration can benefit individuals and households, it can also lead to brain drain in home countries, complicating development efforts by reducing the local talent pool. This complexity highlights the need for balanced policies that protect human rights while addressing rural poverty through sustainable and equitable means. Integrating economic and social policies is essential for advancing rural development, yet it is also crucial to consider the challenges associated with migration as a poverty reduction strategy. By addressing the potential drawbacks, such as brain drain, policymakers can develop more holistic approaches to rural development that support sustainable growth and mitigate the unintended consequences of migration.

***Blue cluster: agricultural foundations and policy in rural development*:** This cluster centers around "agriculture," "farmers," "land use planning," "agriculture policy," and "rural development project." It underscores the foundational role of agriculture in rural economies, focusing on improving agricultural practices, policy-making, and land use efficiency. Key themes include farmer attitudes toward policies, sustainable agricultural practices, and optimizing agricultural resources to support rural livelihoods and development projects.

Agriculture is central to rural development, significantly impacting economic stability and sustainability. Effective agricultural policies and practices are essential for enhancing farmer participation, optimizing land use, and addressing pressing challenges like climate change and food insecurity. Promoting sustainable agricultural practices, particularly CSA, is crucial for enhancing resilience among smallholder farmers, especially in low-income countries. Policies

supporting CSA practices, such as improved water management and agroforestry, drive adoption among smallholders (van Asseldonk et al., 2023). An integrated approach that combines subsidies, training, and other policy instruments further strengthens CSA adoption by promoting a holistic perspective on agricultural practices, taking into account both direct and indirect impacts on the farming ecosystem (van Asseldonk et al., 2023).

Policies incorporating local knowledge and prioritizing farmer participation are vital to creating resilient and sustainable rural landscapes. Inclusive policy models that value farmers' insights and decision-making abilities have been shown to be effective in developing sustainable practices (McDonagh, 2022). For instance, case studies from West Ireland demonstrate that farmer engagement in land management enhances the effectiveness of these practices and fosters a sense of ownership, which is crucial for long-term success (McDonagh, 2022). By valuing local input, these models ensure that policies align with on-the-ground realities and support sustainable development.

Historically, agricultural policies have often overlooked marginal lands, vital for supporting vulnerable populations and addressing the interconnected challenges of food security, poverty, and environmental sustainability. A new policy framework is needed to prioritize these marginal areas and address the food-poverty-environment nexus (Ahmadzai et al., 2021). Future policies should target geographic hotspots of marginality, emphasizing regenerative agricultural practices to increase productivity while enhancing environmental sustainability (Ahmadzai et al., 2021). This approach supports those most in need and promotes ecological balance in areas often susceptible to degradation. While these policies and practices are essential for advancing rural development, challenges remain, particularly in ensuring equitable resource distribution and catering to the diverse needs of farmers across various regions. Achieving sustainable agricultural outcomes requires a balanced approach that integrates both top-down directives and bottom-up, locally informed practices.

***Limitations and future research*:** This study highlights the evolution of agricultural technology and rural development research, demonstrating the increasing emphasis on sustainability, climate-smart agriculture, and digital innovations. The bibliometric analysis reveals significant research clusters, identifies key contributors, and underscores the growing interdisciplinary nature of the field. The findings suggest that agricultural technology and rural development are becoming more interconnected, with a shift toward policy-driven and environmentally sustainable approaches. However, while this study provides valuable insights, several limitations should be acknowledged.

One limitation is the reliance on the Scopus database, which, although comprehensive, may exclude relevant publications from other sources such as Web of Science or regional repositories. Future studies could incorporate multiple databases to provide a more exhaustive analysis. Additionally, bibliometric analysis focuses on quantitative research patterns rather than qualitative content, meaning that more profound contextual interpretations of research findings are beyond the study's scope. Future research could complement bibliometric methods with systematic reviews or meta-analyses to better understand the themes and impacts of agricultural technology and rural development research.

Another limitation is the evolving nature of research trends, where recent publications may not yet have accumulated enough citations to be fully recognized in bibliometric mapping. To address this, future studies could apply dynamic citation analysis to track how emerging topics gain influence over time. Furthermore, while this study identifies key research collaborations, it does not delve into the effectiveness of these partnerships in translating research into policy implementation or real-world agricultural improvements. Future research could investigate the impact of collaborative networks on policy outcomes and technology adoption in rural settings.

***Conclusion*:** This study provides a comprehensive bibliometric analysis of research trends in agricultural technology and rural development, highlighting key contributors, emerging themes, and evolving research priorities. The findings reveal a shift from traditional agricultural practices to climate-smart agriculture, digital innovations, and policy-driven sustainability efforts, reflecting the field's growing interdisciplinary nature. Co-authorship networks indicate strong international collaborations, particularly among the United States, India, and Germany, while citation analysis identifies influential publications shaping research directions. Despite these insights, limitations such as database restrictions and citation lag suggest the need for future studies to incorporate multiple data sources, conduct qualitative analyses, and explore the real-world impact of research collaborations. This study informs policy decisions, academic priorities, and practical innovations by bridging agricultural technology and rural development research, contributing to a more sustainable and resilient agrarian future.

The analysis of co-authorship and keyword networks further emphasizes the interdisciplinary nature of agricultural technology research, showcasing collaborations across regions and disciplines. Emerging interests in digital technology, environmental sustainability, and socio-economic policy complement central themes like rural development, agriculture, and regional planning. This interconnected structure illustrates the field's responsiveness to traditional agricultural needs and evolving challenges, fostering collaborative networks that integrate scientific, socio-economic, and policy-based approaches to rural development.

The study demonstrates that agricultural technology and rural development have transformed from foundational research on basic practices to a complex, multidisciplinary field addressing global sustainability goals. Future research can build on these findings by exploring the practical applications of innovative technologies and sustainable practices in diverse rural contexts. This study provides scholars, policymakers, and practitioners with a roadmap to further enhance agricultural resilience, rural community welfare, and sustainable development through continued interdisciplinary research and collaboration.

***CRediT author statement*:** All authors have equally contributed to this study from its inception to the completion of the final manuscript, including its submission to the journal editor.

***Conflict of interest*:** The authors declare that no conflicts of interest are associated with this study.

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***Ethical statement*:** This study is based solely on software and hardware applications, and biological organisms are not involved.

***Availability of data and materials*:** The data supporting the findings of this research are accessible upon reasonable request from the corresponding author.

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***SDGs' addressed*:** Zero Hunger; Climate Action; Life on Land.

***Policy referred*:** Policy Integration as a Central Theme, Influence of Research on Policy Frameworks

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